TECHNICAL SPECIFICATIONS OF GEOTEXTILE AND APPLICATIONS IN MARINE WORKS

Hassan Salah

Principal Offshore Engineer, M.Sc. civil Engineering, Cairo, Egypt.

Abstract – *Geosynthetics play an important role in many civil engineering applications, especially soil stabilization, railways, coastal structures and water resources. It is often used to achieve economic and technical benefits. Geotextile is one of the types of geosynthetics that is called in American Standards as "A permeable geosynthetic comprised solely of textiles". Geotextile performs one or more important functions in marine works such as; filtration, separation, drainage, erosion control and reinforcement. The needs of geotextiles are increasing day by day in developing countries like Egypt due to the strong development in infrastructures of roads, railways, ports and terminals, marine works, etc.*

This paper provides details of technical specifications about the effective properties, required tests, functions and minimum requirements that should be taken into account during selection of geotextiles. In addition, it defines the geotextiles minimum requirements stipulated in the codes and standards that make engineers qualified enough to specify and select geotextile that fit the purpose of use.

The technical details and conclusions of this paper are highly useful for engineers working in the design and implementation of marine fields to be sufficiently qualified when identifying and selecting geotextiles to fit the purpose of use.

Key Words: Geosynthetics, Marine works, Geotextiles, Woven and non-woven, Polymers, Fabrics.

1. INTRODUCTION

Geosynthetics are used in marine projects, roads, transportation, river embankment, etc. to strengthen and improve their efficiency. The main reasons behind the growth of the geosynthetics industry in recent decades are the development of its basic characteristics such as corrosion resistance, durability, flexibility, ease of storage and installation, environment friendly, resistance to biological and chemical degradation, etc. [1].

There are many types of geosynthetics used in several engineering applications such as; Geotextiles, Geogrids, Geomembranes, Geosynthetic clay liners, Geofoam, Geocells, Geocomposites, and Geonets. Due to the wide range of geosynthetics, they are selected according to the type of functions.

Table -1 summarizes the different types of geosynthetics and their functions to help engineers in selecting the appropriate type of geosynthetic for any project [2]. It is also noted in Table -1 that geotextiles and geocomposites cover most of the functions, so they are used in many applications.

Table -1: Function of Geosynthetics Types

Geosynthetics Types	Filtration	Separation	Reinforcement	Drainage	Containment	Protection	Erosion Control
Geotextile	x	x	x	x	-	x	-
Geocomposite	x	x	x	x	x	-	-
Geotextile Tube	-	-	-	-	-	x	x
Geomembrane	-	-	-	-	x	-	-
Geogrid	-	-	x	-	-	-	-
Geosynthetic Clay liner	-	-	-	-	x	-	-
Geocells	-	-	x	x	-	-	-
Geofoam	-	x	-	-	-	-	-
Geonets	-	-	-	x	-	-	-
Natural Fiber Geosynthetics	x	x	x	x	-	-	-

Moreover, when selecting geosynthetics, the engineer should be familiar with some of the properties of polymers as they are the main factor affecting the geosynthetics industry (see Table -2). Table -2 shows that the polyester is very high in tensile strength, unit weight, UV light, melting temperature and cost with low in strain only. Therefore polyester geosynthetic is recommended for reinforcement applications. On the other side, polyethylene geosynthetic is recommended for separation and filtration applications. However, in the case of many geosynthetics that fulfil the minimum requirements for the required application, geosynthetic should be selected on a cost basis.

Table -2: Properties of Polymers used in geosynthetics industry [3]

Properties	Polymers Types			
	Polyester	Polyamide	Polypropylene	Polyethylene
Tensile strength	High	Medium	Low	Low
Elastic modulus	High	Medium	Low	Low
Strain at failure	Low	Medium	High	High
Unit weight	High	Medium	Low	Low
Ultraviolet (UV) light	High	Medium	High	High
Melting Temp.	High	High	Medium	Medium
Cost	High	Medium	Low	Low

The aim of this paper in general is to introduce the types of geosynthetics, their functions and important properties, then highlight the geotextile that is commonly used in marine works and summarize its functions, tests, properties, and the minimum requirements stated in the codes and standards that make engineers sufficiently qualified to specify and select geotextile properties that fit for purpose of a particular engineering problem.

This paper is organized as follows: the next section introduces geotextiles an overview. Section 3 describes the geotextile properties and tests. Section 4 describes the geotextile requirements. Finally, conclusions and recommendations are reported in the last section.

2. GEOTEXTILES OVERVIEW

Geotextile is widely used in maritime structures such as breakwater, revetment and shore protection, etc. Generally, geotextile should allow water to flow while retaining the soil. Other coastal applications, such as soil bank reinforcement, depend on the high tensile strength of the geotextile [3].

CEM (2006) stated that the most common use of geotextiles in marine works is as a filter between fine material (e.g. sands or soils) and coarse material (e.g. gravel or small stone) that forms the first layer of coastal structures. For typical usage of geotextile in marine works see Figure -1 [3].

Both woven and nonwoven geotextiles are generally used for coastal applications, but woven monofilament geotextiles are highly preferred for coastal structures [3].

The Textile Institute in Manchester defined geotextiles as "Any permeable textile material used for filtration, drainage, separation, reinforcement and stabilization purpose as an integral part of civil engineering structures of earth, rock or other constructional materials" [4].

Geotextiles are made from either natural fibres or synthetic fibres. The important plant used in natural fibres are jute, sisal, flax, hemp, abaca, ramie and coir, while the raw materials used for synthetic fibres are the polymer families (i.e. polypropylene, polyester, polyamide and polyethylene) [5].

Using the natural fibres in various engineering applications have been investigated and described in many literatures such as Rao et al. (2000) [6], Lekha (2004) [7], Lekha et al. (2006) [8], Rawal & Anandjiwala (2007) [9].

Although the use of natural fibres in the geotextile industry has many advantages (such as; low cost, robustness, availability and environment friendly), its ability to biodegrade makes it used for short-term functions other than synthetic fibres [10].

Geotextiles are classified into the following classes based on the manufacturing process (see Figure-2) [11].

- Woven geotextile: A geotextile produced by interlacing, usually at right angles, two or more sets of yarns (made of one or several fibers) using a conventional weaving process.
- Nonwoven geotextile: A geotextile produced from directionally or randomly oriented fibers into a loose web by bonding with partial melting, needle-punching, or chemical binding agents (i.e. glue, rubber, latex, cellulose derivative, etc.).
- Knitted geotextile: A geotextile produced by inter-looping one or more yarns together with a knitting machine.
- Stitched geotextile: A geotextile in which fibers or yarns or both are interlocked/bonded by stitching or sewing.

The filter function in marine works can be achieved by using granular materials or geotextiles or a combination between them as shown in Figure -3 [1].

For marine works, many researchers mentioned in their literature that the geotextile filter (either alone or in combination with granular filter) is preferred more than the granular filter alone for the following reasons:

- Easy to install;
- More economical;
- Ensures continuity and uniformity, whether above or below the water level;
- Easy to quality control.

However, it is usually recommended that a layer of aggregate (e.g. granular filter) be placed between the geotextile and the layer of rocks/concrete blocks to prevent geotextile degradation by ultraviolet and to protect it from damage caused by large rocks or blocks. Moreover, it will create a uniform pressure on the geotextile that ensures proper filtration.

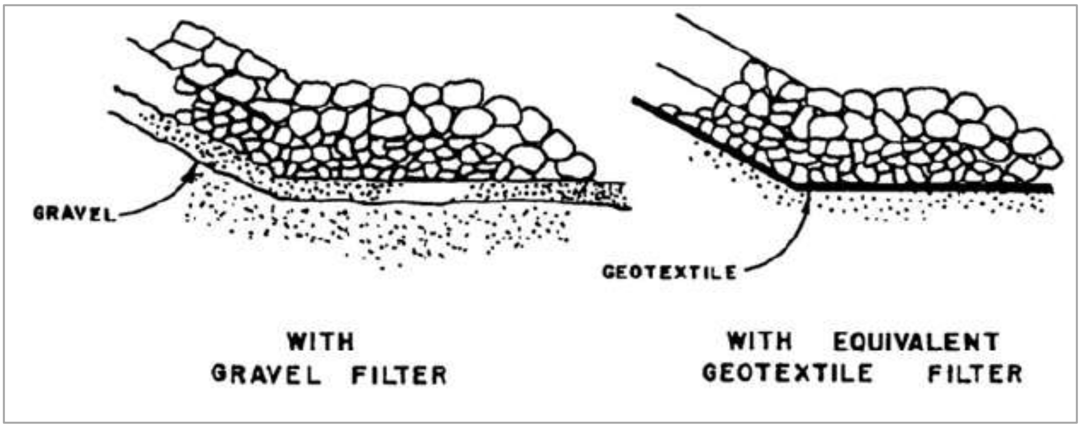

Fig -1: Typical usage of geotextile in marine works [3]

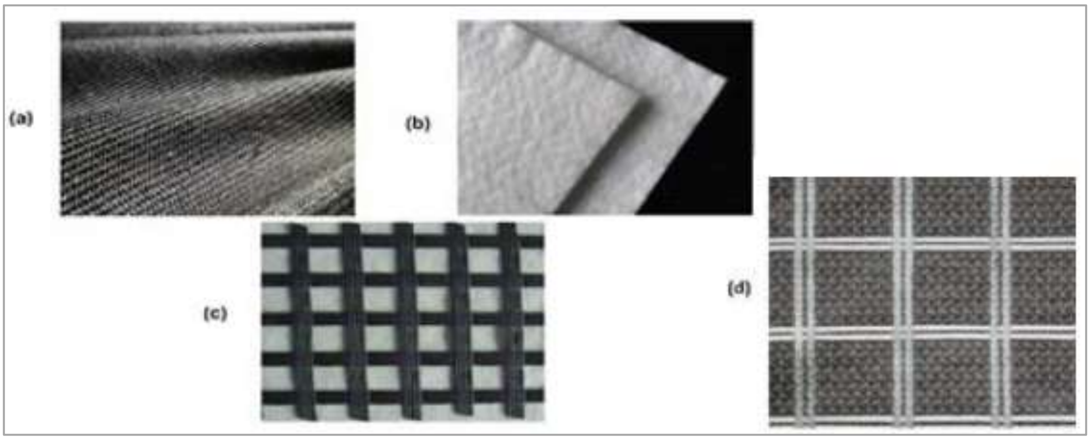

Fig -2: Geotextile classifications, (a) Woven; (b) Nonwoven; (c) Knitted; (d) Stitched [11]

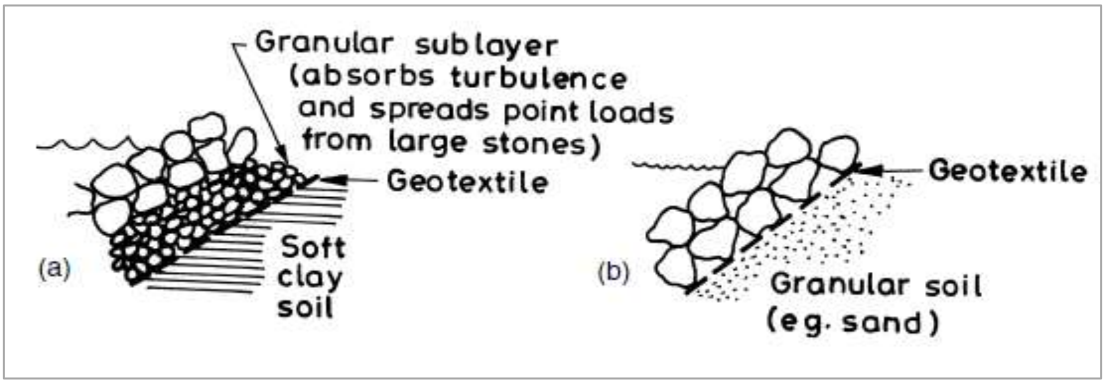

Fig -3: Geotextiles filter in marine works [1]

3. GEOTEXTILE PROPERTIES AND TESTS

Most of values of geotextile properties are expressed as a Minimum Average Roll Value "MARV", except AOS. Statistically, MARV is equal to the average (μ) value minus two times the standard deviation (σ), see Figure -4.

If the geotextile sample of size n have values of one property as $N_1, N_2, N_3, \ldots, N_n$, the MARV for this sample will be determined as follows:

$$\mu = \frac{N_1 + N_2 + N_3 + \cdots + N_n}{n} \quad (1)$$

$$\sigma = \sqrt{\frac{(N_1 - \overline{\mu})^2 + (N_2 - \overline{\mu})^2 + \cdots + (N_n - \overline{\mu})^2}{N - 1}} \quad (2)$$

$$MARV = \mu - 2\,\sigma \quad (3)$$

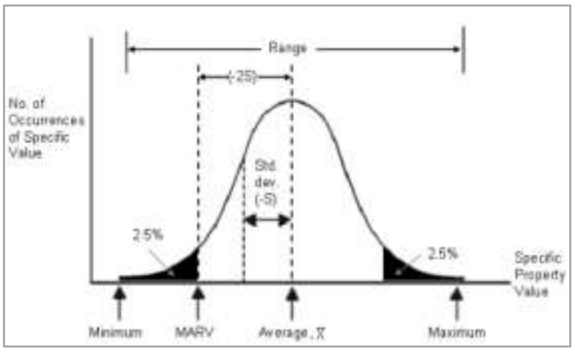

Fig -4: MARV on the normal distribution curve

Table -3 summarize the basic properties, functions and ASTM standards used to select and specify the geotextiles.

Table -3: Geotextiles Properties, Functions and Standards

Properties	Functions	ASTM Standard
Tensile Strength	Separation, Filtration, Reinforcement	D4595
Grab Tensile Strength & Elongation	Separation, Filtration, Reinforcement	D4632
Tear Strength	Separation, Protection, Reinforcement	D4533
Puncture Strength	Separation, Protection, Reinforcement, Filtration,	D6241
Apparent Opening Size	Separation, Drainage, Reinforcement, Filtration,	D4751
Permittivity	Separation, Drainage, Reinforcement, Filtration,	D4491
UV Resistance	Separation, Protection	D4355

3.1 Tensile Strength Test

This test includes the measurements of tensile strength as well as elongation of geotextile using a wide-width strip specimen tensile method according to ASTM D4595. It is recommended that the specimen size used in the test are 200 mm wide and 100 mm long as shown in Figure -5.

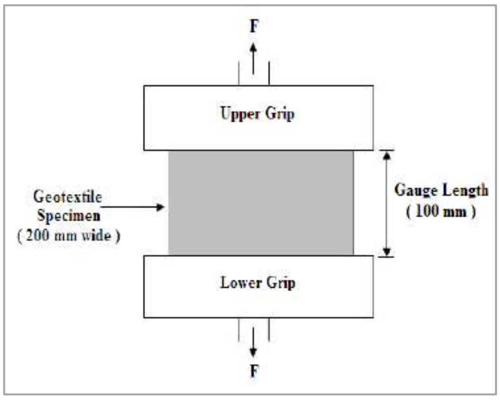

Fig -5: Wide Width Tensile Test Specimen [12]

The specimen will be subjected to a tensile load gradually with a strain rate of approximately 10 mm/min up to the specimen failure. The load per meter width of the specimen is reported in the form of a wide width tensile strength (KN/m) and also the elongation should be reported as a percentage (%) of the original measurement length [12].

3.2 Grab Tensile Test

This test provides the breaking load (Grab Strength) and elongation (Grab Elongation) of geotextiles. According to ASTM D4632, the specimen will be 100mm x 200mm and secured using 25mm x 50mm grips (jaws) as shown in Figure -6.

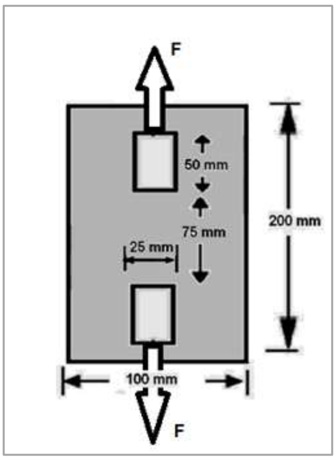

Fig -6: Grab Tensile Test Specimen

Test speed is 300mm/min (± 10 mm/min) as the load is applied longitudinally to specimen and the test is carried to rupture. Both grab tensile strength and corresponding elongation in percentage (%) of the original measurement length. Grab tensile strength is measured in N.

Figure -7 simulates this test as in the field situation. This test is useful for a quality control and acceptance testing of commercial shipments for geotextiles.

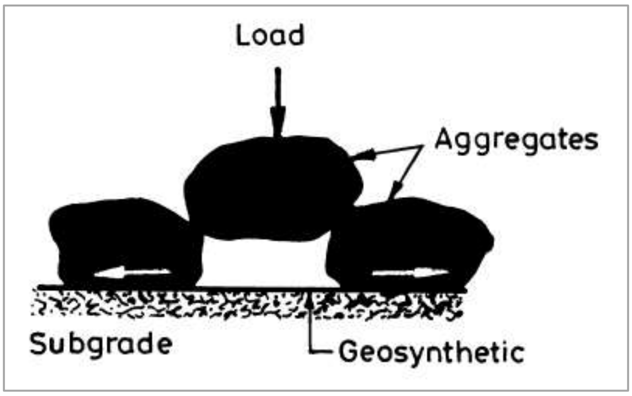

Fig -7: Grab Tensile Strength Test "Field Situation" [1]

3.3 Trapezoidal Tear Test

This test method is used to measure the force required to continue a tear in geotextiles by the trapezoid method. This test is useful for quality control and acceptance testing. According to ASTM D4533, specimen test size will be 200mm x 76mm and the specimen will be gripped along two non-parallel sides of the trapezoidal in the jaws of a tensile machine as shown in Figure -8. Preliminary cut 15mm long at the center of the 25mm edge should be made to start the tearing process. Trapezoidal tear strength is measured in N.

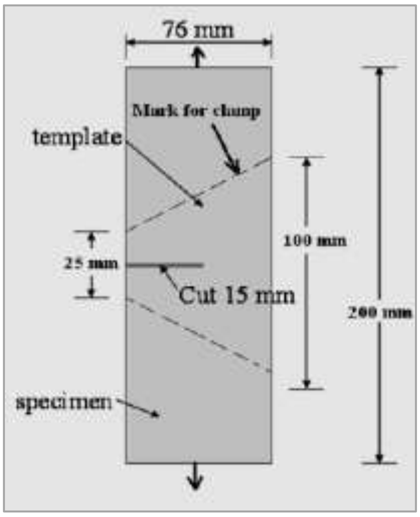

Fig -8: Trapezoidal Tear Test Specimen

3.4 Puncture Strength Test

The American Association of State Highway and Transportation Officials (AASHTO) replaced ASTM D4833 (Pin test) with the ASTM D6241 Standard Test Method for the Static Puncture Strength (in N) of Geotextiles which is called a California Bearing Ratio (CBR) [13]. CBR test used the probe diameter 50mm instead the probe diameter 8mm was used in Pin test as shown in Figure -9.

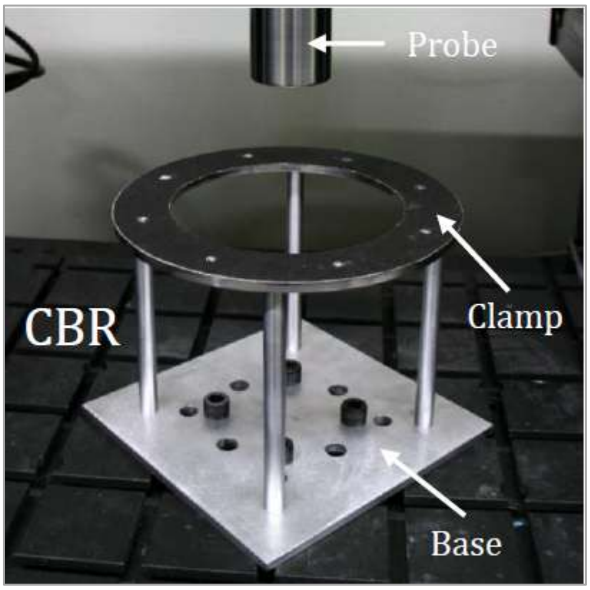

Fig -9: Puncture Strength Test (CBR Test) [13]

A circular geotextile specimen will be gripped between two clamping rings. Internal diameter of this clamping rings is 150mm, therefore, the specimen size will be 220mm x 220mm. A constant rate (50mm/min) of displacement of this test is applied perpendicular through the center of test specimen until rupture.

The geotextiles must withstand local stress of any object causing a puncture in the geotextile such as aggregates. In addition, the pressure applied normally on the geotextile, called burst load, shall also withstand. Figure -10 simulates the puncture and burst loads as in the field situation.

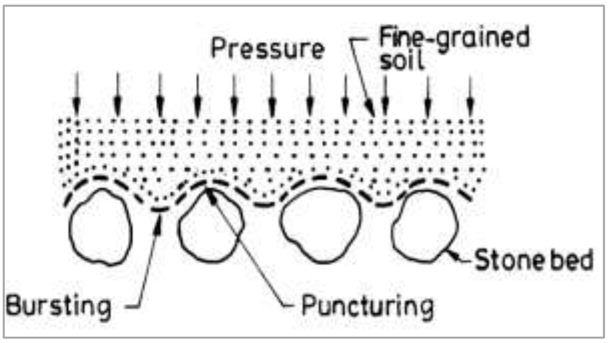

Fig -10: Puncturing and Bursting "Field Situation" [1]

3.5 Bursting Strength Test

Bursting strength of geotextile is defined as the ability to withstand pressures that apply normally to its plane while it is restricted from all directions in the same plane as shown in Figure -10 in subsection 3.4. The Bursting strength is measured and reported in KPa.

ASTM D3787 is used to determine the force required to rupture geotextile specimen by forcing a steel ball through the fabric with a Constant-Rate-of-Traverse (CRT) tensile tester. This test can be performed using air pressure applying normally on geotextile instead of the ball burst.

The steel ball shall have a diameter of 25.40 mm and the ring clamp shall have an internal diameter of 44.45 mm (see Figure -11).

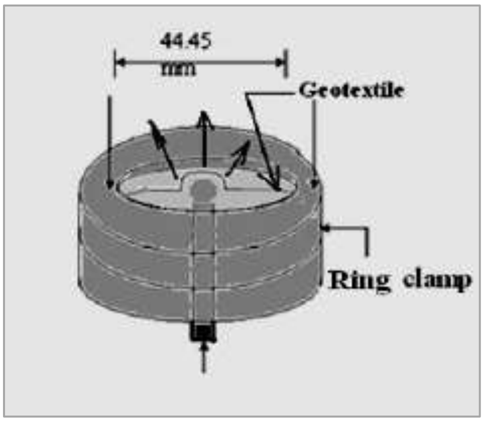

Fig -11: Ball Bursting Test

The specimen size shall be at least 125mm square, or a circle 125mm in diameter. The specimen is placed without tension in the ring clamp and securely fastened by means of a screw. The CRT tensile testing machine is started using a pulling clamp speed of 305mm/min (±13 mm/min) and continuing at that speed until the specimen bursts.

The size of stone aggregate has a significant impact on the burst strength of the geotextile, as the burst strength of the geotextile with large stones is greater than with small stones.

3.5 Apparent Opening Size Test

This test method is used to determine the apparent opening size (AOS) in the geotextiles (in mm or micron "µm") which expresses the largest opening dimension available for soil to pass through. According to ASTM D4751 this test is based on dry sieving method.

AOS is expressed in other standards as "Equivalent Opening Size" (EOS) or the opening size in geotextile for which 90 % are smaller "$O_{90\ geotextile}$" based on pore size distribution curves.

In general, the AASHTO M288 for geotextile has recommended the maximum values of AOS, in relation to the percentage of soil passing through a 0.075mm sieve (sieve No. 200), to be as follows:

- 0.43 mm for less than 15%;
- 0.25mm for 15 to 50%
- 0.22 mm above 50%.

However, for cohesive soils with a plasticity index (PI) more than 7, the Maximum Average Roll Values for AOS will be 0.30 mm.

It should be noted that Values of AOS are expressed as a Maximum Average Roll Values (MRAV).

$$\text{MARV} = \mu + 2\,\sigma \quad (4)$$

3.6 Permittivity Test

This test indicates to the water permeability of geotextile by a so-called permittivity (Ψ). The permittivity is equal the coefficient of permeability (k_n in dimension "LT^{-1}") for water flow normal to geotextile plane divided by thickness (Δx in dimension "L") of geotextile, and therefore the permittivity unit is "S^{-1}" (see equation-5).

$$\Psi = \frac{k_n}{\Delta x} \quad (5)$$

This test shall be performed according to ASTM D4491 to determine the permittivity of geotextiles using constant head test or falling head test.

3.7 Ultraviolet Resistance Test

The ultraviolet (UV) test is a standard test for deterioration of geotextiles by exposure to light, moisture and heat in xenon arc type apparatus.

This test describes the allowable deterioration in tensile strength of any permeable geotextile material according to ASTM D4355.

The specimen size for this test is 50mm x 150 mm that will be exposed for 0, 150, 300, and 500 hours of UV exposure in a xenon-arc device. The exposure consists of 120 min cycles as follows: 90 min of light only at 65 ± 5C black panel temperature, and 30 ± 5% relative humidity, followed by 30 min of light with water spray.

After the exposure time, the specimens are subjected to tensile strength test. It should be noted that the minimum percentage retained strength of geotextile after this test should not be less than 50%.

4. GEOTEXTILE REQUIREMENTS

The American Association of State Highway and Transportation Officials (AASHTO M288 Geotextile Specifications) classified the geotextile for the following three classes to assess the engineers during geotextile design and selection:

- Class 1: For more sever installation conditions.
- Class 2: When site conditions are unknown.
- Class 3: For less sever installation conditions.

Table -4 provides the classes required for some geotextile applications. The properties for geotextile classes that are required for installation survivability are represented in Table –5 according to AASHTO M288 [14]. Each Class is subdivided according to elongation (%) resulted from the grab strength test.

Tables -6, 7, 8 & 9 show the hydraulic properties of the geotextile according to its application.

The geotextile should be conform to all properties and requirements mentioned in Tables -4 to 9.

Table -4: Geotextile Applications and required Classes [1] & [14]

Geotextile Applications	Geotextile Classes
Filtration applications in subsurface drainage	2
Separation of soil subgrades (soaked CBR ≥ 3; or Shear Strength ≥ 90 kPa)	2
Stabilization of soft subgrades (soaked 1 < CBR < 3; or 30 kPa < Shear Strength < 90 kPa)	1
Permanent erosion control (for example, geotextiles beneath rock riprap)	2 for woven monofilament, 1 for all other geotextiles

Table -5: Geotextile Classes Minimum Requirements [1], [12], [14] & [15]

Property	ASTM test method	Units	Geotextile Class[1,2]					
			Class 1 Elongation[3]		Class 2 Elongation[3]		Class 3 Elongation[3]	
			<50%	≥50%	<50%	≥50%	<50%	≥50%
Tensile strength	D4595	KN/m	30	20	20	15	15	10
Grab strength	D4632	N	1400	900	1100	700	800	500
Sewn seam strength[4]	D4632	N	1260	810	990	630	720	450
Tear strength	D4533	N	500	350	400[5]	250	300	180
Puncture strength	D4833	N	500	350	400	250	300	180
Burst strength	D3786	kPa	3500	1700	2700	1300	2100	950
Ultraviolet (UV) stability	D4355	%	50% retained strength after 500 h of exposure					

Notes:

1. The hydraulic properties for the geotextile as per application are specified in Tables 6, 7, 8 & 9 hereafter. The severity of installation conditions for the application generally dictates the geotextile Class. Class 1 is specified for more severe or harsh installation conditions where there is a greater potential for geotextile damage, Classes 2 and 3 are specified for less severe conditions.
2. All values express the MARV in the weakest principal direction (for MARV, see Figure -4 above).
3. Elongation % is according to ASTM D4632 that used for the grab strength test.
4. If sewn seam strength is required.
5. For woven monofilament geotextiles, the required MARV for tear strength is 250 N.

Table -6: Geotextile Hydraulic Properties for Filtration in Subsurface Drainage [1] & [14]

Property	**ASTM test method**	**Units**	**Requirements (% in-situ soil passing 0.075 mm [1]) No. 200 sieve**		
			<15 %	**15 % to 50 %**	**>50 %**
Strength	Class 2 from Table -5 [2]				
Permittivity [3,4]	D4491	S^{-1}	0.5	0.2	0.1
Apparent Opening Size (AOS) [3,4]	D4751	mm	0.43 Max. Avg. Roll Value (see equation-4)	0.25 Max. Avg. Roll Value (see equation-4)	0.22 [5] Max. Avg. Roll Value (see equation-4)

Notes:

1. Based on grain-size analysis of in-situ soil in accordance with AASHTO T88.
2. The engineer may specify a Class 3 geotextile from Table -5 for trench drain applications based on; (I) field experience, (II) laboratory testing, or (III) subsurface drain depth < 2 m, drain aggregate < 30 mm in diameter and compaction requirement < 95% of AASHTO T99.
3. These default filtration property values are based on the predominant particle sizes of in-situ soil.
4. Site-specific geotextile design should be performed especially if one or more of the following problematic soil environments are encountered: unstable or highly erodible soils such as non-cohesive silts, gap-graded soils, alternating sand/silt laminated soils, dispersive clays, and/or rock flour.
5. For cohesive soils with a Plasticity Index (PI) > 7, geotextile Maximum Average Roll Value for AOS is 0.30 mm.

Table -7: Geotextile Hydraulic Properties for Separation [1] & [14]

Property	**ASTM test method**	**Units**	**Requirements**
Strength	Class 2 from Table -5 [1]		
Permittivity	D4491	S^{-1}	0.02 [2]
Apparent Opening Size (AOS)	D4751	mm	0.60 Max. Avg. Roll Value (see equation-4)

Notes:

The separation requirements will be applicable to the use of geotextile at the subgrade level if the soaked CBR ≥ 3 or shear strength ≥ 90 KPa. These are appropriate for unsaturated subgrade soils.

1. The engineer may specify a Class 3 geotextile from Table -5 based on; (I) Field experience, (II) Laboratory testing, (III) Aggregate cover thickness of the first lift over the geotextile > 300 mm and the aggregate < 50 mm in diameter, or (VI) Aggregate cover thickness of the first lift over the geotextile > 150 mm, aggregate < 30 mm IN diameter and construction equipment pressure < 550 kPa.
2. Default value, however, the permittivity of geotextile (Ψ_{geo}) should be greater than that of the soil (Ψ_{Soil}). The engineer may also need the permeability of the geotextile (k_{geo}) to be greater than that of the soil (k_{Soil}).

Table -8: Geotextile Hydraulic Properties for Stabilization [1] & [14]

Property	**ASTM test method**	**Units**	**Requirements**
Strength	Class 1 from Table -5 [1]		
Permittivity	D4491	S^{-1}	0.05 [2]

Apparent Opening Size (AOS)	D4751	mm	0.43 Max. Avg. Roll Value (see equation-4)

Notes:
The stabilization requirements will be applicable to the use of a geotextile layer at the subgrade level to provide the coincident functions of separation, filtration and reinforcement if the subgrade soil is in wet, saturated conditions due to a high groundwater table or due to prolonged periods of wet weather. Stabilization is appropriate if the subgrade soils are having soaked 1 < CBR < 3; or 30 kPa < Shear Strength < 90 kPa.

1. The engineer may specify a Class 2 or 3 geotextile from Table -5 based on; (I) Field experience, or (II) Laboratory testing.
2. Default value, however, the permittivity of geotextile (Ψ_{gio}) should be greater than that of the soil (Ψ_{Soil}). The engineer may also need the permeability of the geotextile (k_{geo}) to be greater than that of the soil (k_{Soil}).

Table -9: Geotextile Hydraulic Properties for Permanent Erosion Control [1] & [14]

Property	ASTM test method	Units	Requirements (% in-situ soil passing 0.075 mm [1]) No. 200 sieve		
			<15 %	15 % to 50 %	>50 %
Strength	For woven monofilament geotextiles, Class 2 from Table -5[2] For all other geotextiles, Class 1 from Table -5 [2,3]				
Permittivity [1,4]	D4491	S^{-1}	0.7	0.2	0.1
Apparent Opening Size (AOS)[3,4]	D4751	mm	0.43 Max. Avg. Roll Value (see equation-4)	0.25 Max. Avg. Roll Value (see equation-4)	0.22 [5] Max. Avg. Roll Value (see equation-4)

Notes:
The erosion control requirements will be applicable to the use of a geotextile layer between energy absorbing armor system and the in-situ soil to prevent soil loss resulting in excessive scour and to prevent hydraulic uplift pressures causing instability of the permanent erosion control system.

1. Based on grain-size analysis of in-situ soil in accordance with AASHTO T88.
2. As a general guideline, the default geotextile selection is appropriate for conditions of equal or less severity than either of (I) Armor layer stone weights ≤ 100 kg, stone drop height is < 1m, and no aggregate bedding layer is required, or (II) Armor layer stone weighs > 100 kg, stone drop height is < 1m, and the geotextile is protected by a 150mm thick aggregate bedding layer designed to be compatible with the armor layer.
3. The engineer may specify a Class 2 geotextile from Table -5 based on; (I) Field experience, (II) Laboratory testing, (III) Armor layer stone weighs < 100 kg, stone drop height is < 1m, and the geotextile is protected by a 150 mm thick aggregate bedding layer designed to be compatible with the armor layer, and (VI) Armor layer stone weights < 100 kg and stone is placed with a zero-drop height.
4. These default filtration property values are based on the predominant particle sizes of in-situ soil.
5. Site-specific geotextile design should be performed especially if one or more of the following problematic soil environments are encountered: unstable or highly erodible soils such as non-cohesive silts, gap-graded soils, alternating sand/silt laminated soils, dispersive clays, and/or rock flour. However, for cohesive soils with a Plasticity Index (PI) > 7, geotextile Maximum Average Roll Value for AOS is 0.30 mm.

5. CONCLUSIONS & RECOMMENDATIONS

In this paper, a geotextile for the marine works and their properties and functions was investigated and summarized from the standards, textbooks and literatures based on our experience in the field of ports and terminals. The study concluded the following:

- It is noted that geotextile, as a type of geosynthetics, covers most of the functions and applications of the marine works as shown in

Table -1 (i.e. filtration, separation, reinforcement, drainage, containment, protection and erosion control).

- In the stage of geotextile selection, engineers should be familiar with the types of polymers and their properties that are the main factor in the geotextile industry. Moreover, the engineers should be aware of the minimum requirements stated in the standards to qualify them to select geotextiles carefully.

- It is worth mentioning that the minimum percentage of the retained tensile strength of a geotextile after UV test should not be less than 50%.

- It is preferable to place a layer of aggregate between the geotextile and the rock layer to prevent it from degradation by UV as well as damage from large rocks. In addition, it will give uniform pressure on the geotextile, which ensures proper filtration.

- When selecting a geotextile, it should be taken into account that the value of AOS or $O_{90\ geotextile}$ is less than $D_{80}$for the soil.

- It is noted that the pores in the woven geotextile are often uniform in their size and distribution. In general, nonwoven geotextiles display smaller pore size (i.e. “AOS” or “O_{90} “) than woven.

- Most of the geotextile properties are expressed in Minimum Average Roll Values (see equation-3), except AOS value as they are expressed as a Maximum Average Roll Values (see equation-4).

- It is worth noting that excessive elongation will distort and enlarge the pores in the geotextile that leads to a change in the filtering characteristics as well as the loss of soil.

- The tensile strength of the geotextile for tearing resistance is very important when geotextile is subjected to harsh conditions (e.g. high wave loads, currents, etc.), whether during installation or operation.

- In general, woven geotextiles have elongation < 50 %, while non-woven geotextiles have ≥ 50% for each geotextile Class.

- Woven fabrics have high tensile strength, high modulus and low strains while non-woven fabrics have high permeability and high strain. Therefore, woven geotextile is preferred to be used for reinforcement function while non-woven for filtration and drainage functions.

- For rubble-mound structures, strong geotextile allow placement of larger stones directly on it, thus reducing the overall structure thickness and layers. However, if large voids occur in the overlying structure layers, soil pressure and hydrostatic pressure may rupture the geotextile material.

- The bursting strength of the geotextile is greatly affected by the size of the stones used, as the bursting strength with large stones is greater than with small stones.

- To reduce rehabilitation costs, it is recommended to use geotextiles that have a high “Burst strength” in order to continue to retain the soil for a long time.

REFERENCES

[1] Shukla, Sanjay Kumar & Yin, Jian-Hua, “Fundamentals of Geosynthetic Engineering”, Published by Taylor & Francis Group, London, UK, 2006. www.eBookstore.tandf.co.uk.

[2] Ayush Mittal, “Geosynthetics: An Overview”, IJSRSET, April2018, Vol. 4, PP. 231-238, Print ISSN: 2395-1990, Online ISSN: 2394-4099.

[3] Coastal Engineering Manual, “Materials and Construction Aspect”, EM 1110-2-1100, Part VI, Change 3. U.S. Army Corps of Engineers, Washington, Sep. 2011.

[4] M. J. Denton & P. N. Daniels, “Textile Terms and Definitions”, 11th Edition, Manchester, UK: Textile Institute, 2002.

[5] Das, Subrata; Paul, Debasree; Fahad, Mir; Islam, Tarikul & Nizam, Md. Eanamul Haque, “Geotextiles A Potential Technical Textile Product”, JSAER, Nov. 2017, Vol. 4, PP. 337-350, ISSN: 2394-2630.

[6] Rao, G. V., Kumar, J. P. S., &Banerjee, P. K., “Characterization of a braided strip drain with coir and jute yarns, Geotextiles and Geomembranes”, 2000, Vol. 6, PP. 367-384, doi: https://doi.org/10.1016/S0266- 1144(00)00006-6.

[7] K.R. Lekha, “Field Instrumentation and Monitoring of Soil Erosion in Coir Geotextile Stabilised Slopes-a Case Study”, Geotextiles and Geomembranes, 2004, Vol. 22, PP.399-413, doi: https://doi.org/10.1016/j.geotexmem.2003.12.003

[8] K. R. Lekha, & V. Kavitha, “Coir geotextile reinforced clay dykes for drainage of low-lying areas”, Geotextiles and Geomembranes, 2006, Vol. 24, PP. 38-51, Doi: https://doi.org/10.1016/j.geotexmem .2005.05.001

[9] A. Rawal & R. D. Anandjiwala, "Comparative Study between Needle punched Nonwoven Geotextile Structures Made from Flax and Polyester Fibres", Geotextiles and Geomembranes, 2007, Vol. 25, PP. 61-65, doi: https://doi.org/10.1016/j.geotexmem.2006.08.001

[10] S.K. Shukla, "Geosynthetics in civil engineering constructions", Employment News, New Delhi, India, March 2003, Vol. 1, No. 48, PP. 1–3.

[11] Ahmed Abdelmawla, "Characterization of uniaxial geogrid pullout mechanism for calcareous sand backfill", M.Sc., April 2007, Cairo University, Egypt, doi: 10.13140/RG.2.2.26400.48642

[12] "Practice Manual for Use of Technical Textiles in Water Resources Works", Ministry of water resources, river development & ganga rejuvenation, April 2019, Issued by: R&D Division, New Delhi, Email: watrnd-mowr@nic.in

[13] Stacy Van Dyke, "Comparison of CBR and Pin Puncture Strength Testing Used in the Evaluation of Geotextiles", M.Sc., May 2014, University of Wisconsin-Milwaukee, Theses and Dissertations. 773. https://dc.uwm.edu/etd/773.

[14] American Association of State Highway and Transportation Officials (AASHTO), "Standard Specifications for Transportation Materials and Methods of Sampling and Testing", AASHTO M288, 1998, 19th edition, Washington, DC.

[15] Korini, Oltion & Muceku, Ylber, "The Geotechnical Evaluation and Constructions Site Improvement in Shëngjini Area, Albania", AJNTS, Sep. 2012, PP. 1-10.

BIOGRAPHIES

Hassan Salah, M.Sc. Civil Engineering, in addition to that I am Certified Naval Engineer from Lloyd's and also a Member of Royal Institution of Naval Architects "RINA", London, UK.

Currently, I work as a Principal Offshore Engineer in the Oil & Gas Industry in Egypt. Also, I have published many papers abroad in several offshore and marine subjects and participated in many International Conferences. My areas of interest are the application of Marine activities such as Jetties, Breakwaters, Fixed Offshore platform, Ports and Terminals, Single Point Mooring (SPM), Artificial Intelligent (A.I.), Machine learning, etc.